André L. Vaillancourt.

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ACIDIC PRECIPITATION IN ONTARIO

February, 1979

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Ontario
Ministry
of the
Environment

The Honourable
Harry C. Parrott, D.D.S.,
Minister

Graham W. Scott,
Deputy Minister

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INTRODUCTION:

This special report is based on excerpts from material presented by Harry C. Parrott, D.D.S., Minister of the Environment and Ministry staff to the Ontario Legislature's Standing Committee on Resource Development in February, 1979.

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An overview by
The Hon. Harry C. Parrott, D.D.S.
Ontario Minister of the Environment

Acidic precipitation is another consequence of our industrial society. The subject is extremely technical and my Ministry's qualified scientists have been working in this field for a number of years.

I would like to interpret the very real significance and threat this presents to the immediate and long-term future of the people of Ontario.

We've been gathering evidence in Ontario for more than 15 years. At first, it seemed our scientists were detecting minor, localized problems.

It has only been over the past year or so that the evidence has started to fit together to give us our first genuine understanding of the real scope of the issue.

I shall discuss briefly the relationship, as I see it, between the unique consumer-oriented North American lifestyle and the ultimate solution to this problem.

We are facing severe consequences from the pattern and nature of the industrialized and affluent lifestyle which has developed on this continent. The physical consequences of acidic precipitation are almost certainly as damaging to parts of the U.S., particularly northeastern New York State, as they are to the most seriously affected areas here.

I believe the economic impact of acidic precipitation to Ontario, if it is unchecked, will be even more severe in proportion than in any part of the U.S.

This is what has been established to date in terms of cause, effect and consequences.

Cause:

The cause is millions of tons of sulphur and nitrogen oxides discharged from combustion and other sources, into the common air where they are oxidized to various sulphates and nitrates. They dissolve in rain and snow and precipitation becomes acidic.

We're talking about 15 million tons of sulphur dioxide every year from sources in the northeastern U.S. and 2 million tons from Ontario sources. And 24 million tons of nitrogen oxides in the U.S. beside 660,000 tons from Ontario.

Effect:

The effect on us in Ontario is at least 140 lakes today which are known to be in trouble. Lakes which have shifted from an alkaline to an acidic balance and which are increasingly unable to support a sport fish population. The effect still to come is a further 48,000 lakes which will go the same way over the next two decades unless something is done on an international scale.

As part of this pattern, there is strong reason to suspect that this shift in balance in our waters increases the load of mercury and other heavy metals which can be taken up by fish, metals which can either be toxic to the fish or can render them unfit for human consumption.

I can't begin to assess the economic impact of this on our tourism and recreation industries and on the thousands of people employed in and dependent upon these industries. I've heard guesses ranging as high as half a billion dollars. These points are, I feel, highly significant in terms of what we must do.

1. *If we eliminated every Ontario source of sulphur and nitrogen oxides, it would have virtually no impact on the continuing damage to our lakes. We produce less than 3 million tons in Ontario as compared to a combined total of 39 million tons in the northeastern U.S.*

2. *As things now stand, we can expect more use of fossil-fuels, especially coal and oil, and therefore more potential production of sulphur and nitrogen oxides, the gases from this combustion. They cause the acidic precipitation problem. The generation of power is one major example. I have been led to believe that the U.S. is turning away from nuclear power plants because of public opposition. This means a major commitment by alternative to coal-fired power plants.*

These are the facts and they have a significant bearing on where we must go from here.

Action Plan:

There are three major thrusts to my Ministry's action plan. These are:

- *abatement on an international scale,*
- *preventative and remedial action,*
- *and continuing scientific investigation.*

The continuing investigation is our most urgent and pressing need. Our accelerated study has given us an increasingly clear picture of the scope and nature of the problem.

But we need more concrete facts.

Our experience with lake neutralization, and related experience in other countries, has shown that we have to develop our liming and treatment techniques further before they can be applied effectively and economically on any broad scale.

In addition, we need to know, both here and in the U.S., just what degree of abatement is required -- which sources must be controlled and by how much.

Remedial Action:

I believe that, at least on an interim measure, some neutralization program will be required to protect lakes which are threatened immediately. And, I know that treatment is essential for some of the lakes already severely affected.

Our priorities in this area are:

- to continue determining the extent of acidification, and, to identify sources,
- to refine and prefect restoration methods,
- and, using this base, to develop a cost-effective treatment program.

International Prevention:

At the same time, we are dealing with the issue at its source. I have already approached Environment Minister Len Marchand, and we have reached agreement on the need for joint federal-provincial research within Canada. We have also agreed on the need for a complementary effort on the U.S. side of the border to develop a solid base for action by provincial, state and federal authorities.

I will continue these initiatives with these goals in mind:

. An international accord on air quality.

. An international air pollution abatement program.

Conclusion:

Acid precipitation has emerged as a large and hidden cost of our industrialized economy and related lifestyle.

But, consider the long-term implications of acidic precipitation and other cumulative environmental effects of our way of life.

I am convinced that there is a price we must pay.

And part of that price is, I am convinced, an ultimate change in our lifestyle.

It is increasingly apparent that the production of the material goods which are inherent in our way of life is having an effect on our quality of life.

Ultimately, we have a choice.

When our fuels pose a threat to our air or water, then we must either reduce our consumption of those fuels or control the threat they present.

So far, our technology has been equal to the task of controlling any hazards. It may always be equal to this task.

But that technology is increasingly expensive. As a result, our material goods are increasingly expensive.

Eventually, if we do not voluntarily change our lifestyle and reduce our consumption, then simple economics and rising costs will force material and energy conservation and a changed lifestyle upon us.

I believe our long-term environmental policy must recognize this as a fact of life. Over the next few decades, we must direct our efforts into two areas, the technological approach to environmental solutions and the conserver approach and achieve a balance.

SUMMARY

What is acidic precipitation?

Naturally-occurring rainfall is slightly acidic because carbon dioxide reacts with moisture in the atmosphere to form carbonic acid.

Precipitation, both rain and snow, is further acidified when oxides of sulphur and nitrogen react chemically with oxygen and moisture in the atmosphere to form stronger acids.

As acidified precipitation falls on forests, rivers and lakes, chemical changes result which threaten to decrease forest productivity and diminish fish populations in many waterways.

Sulphur compounds are found in various primary ores and in virtually every fossil-fuel including coal and oil upon which urban and industrial society heavily depends. Nitrogen compounds are formed during high-temperature combustion of fossil-fuels.

Since the greater part of the world is dependent upon fossil-fuel, acidic precipitation is a world-wide phenomenon. However, for the most part, its predominate undesirable effects are confined to regional and continental scales.

Atmospheric sources of acid have been identified for a number of years as the cause of lake problems in Norway, Sweden and New York State.

Acidic lakes were first identified in Ontario in the early '50s, as a local problem resulting from their proximity to major smelting operations in the Sudbury area.

Since 1975, data collected by Environment Ontario has established that acidic precipitation is having more widespread effects over a broader area that includes some of Ontario's most popular recreation areas. In addition, evidence is being accumulated which supports the conclusion that an important portion of the acidity is due to long-range transport.

Initial work by the Ministry centred on the Sudbury area as part of the Sudbury Environmental Study and concentrated on three aspects:

- Investigating local source contributions.

- Defining the extent of the problem.

- Researching restoration methods.

The Ministry conducted an experimental restoration project which involved artificial neutralization methods in four acidified lakes in the Sudbury area from 1973 to 1977.

The Ministry of the Environment has been studying aspects of acidic precipitation and its effects since 1970 under the auspicies of several ongoing programs. More recently, Provincial Lottery funds have been awarded to the University of Toronto and the Canadian Centre for Inland Waters for related research. The Ministry is working with the federal government in carrying out joint research activities and recently the Minister has approached the federal government with regard to resolving the international implications.

Results to date have established that:

1. The problem of acidified lakes in Ontario is not localized, but extends over a broad area of the Province which includes prime vacation waters.

2. Even in the Sudbury study area, with local SO_2 sources temporarily shut down, acidic precipitation levels have remained constant, indicating that the dominant source lies outside the Sudbury area.

3. Careful study of provincial weather conditions has led to the conclusion that many acid precipitation events can be associated with air flow across the industrial heartland of the United States.

4. There is the likelihood that with increasing demands for energy, and therefore increasing combustion of coal and oil, and subsequent production of the acidifying gases, that the problem will increase in magnitude over the next two decades.

5. Defining and quantifying the extent of this very complex problem will require several years of research and a continued substantial financial commitment from Ontario as well as financial commitments from other jurisdictions.

6. The ultimate solution will require:

   - An international treaty or accord.

   - Joint action with federal governments in Canada and the U.S.

   - Substantial expenditures by public and private sectors -- the private sector to provide adequate source abatement technology and the public sector to maintain artificially the affected aquatic and land ecosystems until the necessary abatement standards are reached.

STATEMENT OF THE PROBLEM

Ontario Ministry of the Environment studies undertaken during the past few years, in addition to their primary objectives, have provided information pointing to the possible widespread adverse effects of acidic precipitation.

These studies are: The Sudbury Environmental Study with the objective of developing criteria and associated rationale, supported by scientifically justifiable information, for the management of air emissions from the mining/smelting industries located in the Sudbury area. The Lakeshore Capacity Study with the objective of quantifying the effects of recreational development on the environment in the Muskoka/Haliburton District of Ontario, and to develop predictive models which will assist development planners in specifying the type and extent of development to be allowed in such recreational areas.

An important and unexpected discovery of the Lakeshore Capacity Study has been the evidence of increasing acidity in many lakes of the Muskoka/Haliburton area and that this phenomenon is being caused by precipitation acidity. Initially, it was felt that the proximity of these lakes to Sudbury and the construction in 1972 of the high stack might provide a possible explanation for this observation. However, subsequent data evaluation and continuing investigations, under the auspices of both of these programs, has demonstrated the nominal contribution of Ontario sources and the very significant impact of non-provincial sources, principally those located in the eastern United States.

Precipitation in Ontario is generally the result of the northerly transport of warm moist air aloft emanating from the Gulf of Mexico. The heavily moisture laden warm air mass rises as it moves north into cooler air. A sample storm track that could cause precipitation is illustrated in Figure 1. The air from which the cloud develops has passed across the heavily industrialized Eastern United States prior to reaching Ontario, and still contains much of the pollutants emitted into it. A list of emissions of sulphur dioxide from some of the major Eastern North American industrialized areas is given in Table 1. Studies have shown that pollutants may be transported thousands of kilometers before they are returned to ground level by various mechanisms of which precipitation is the most important.

From this knowledge an initial appreciation of the relative significance of individual sources can be ascertained, as well as the international scope of the problem. Thus it becomes apparent that no straightforward or simple solution is available to Ontario, as the bulk of the sources lie outside the jurisdiction of the Province.

To further assess the impending magnitude of this problem, several additional facts must be considered. First, the forecast increased demand for electricity coupled with the reluctance to expand nuclear capacity to meet this demand, will likely necessitate significant increases in the use of coal in the very near future. This will aggravate the problem as the coal contains sulphur and is thus a source of acid. Further, the combustion process itself produces oxides of nitrogen which are also known to increase precipitation acidity.

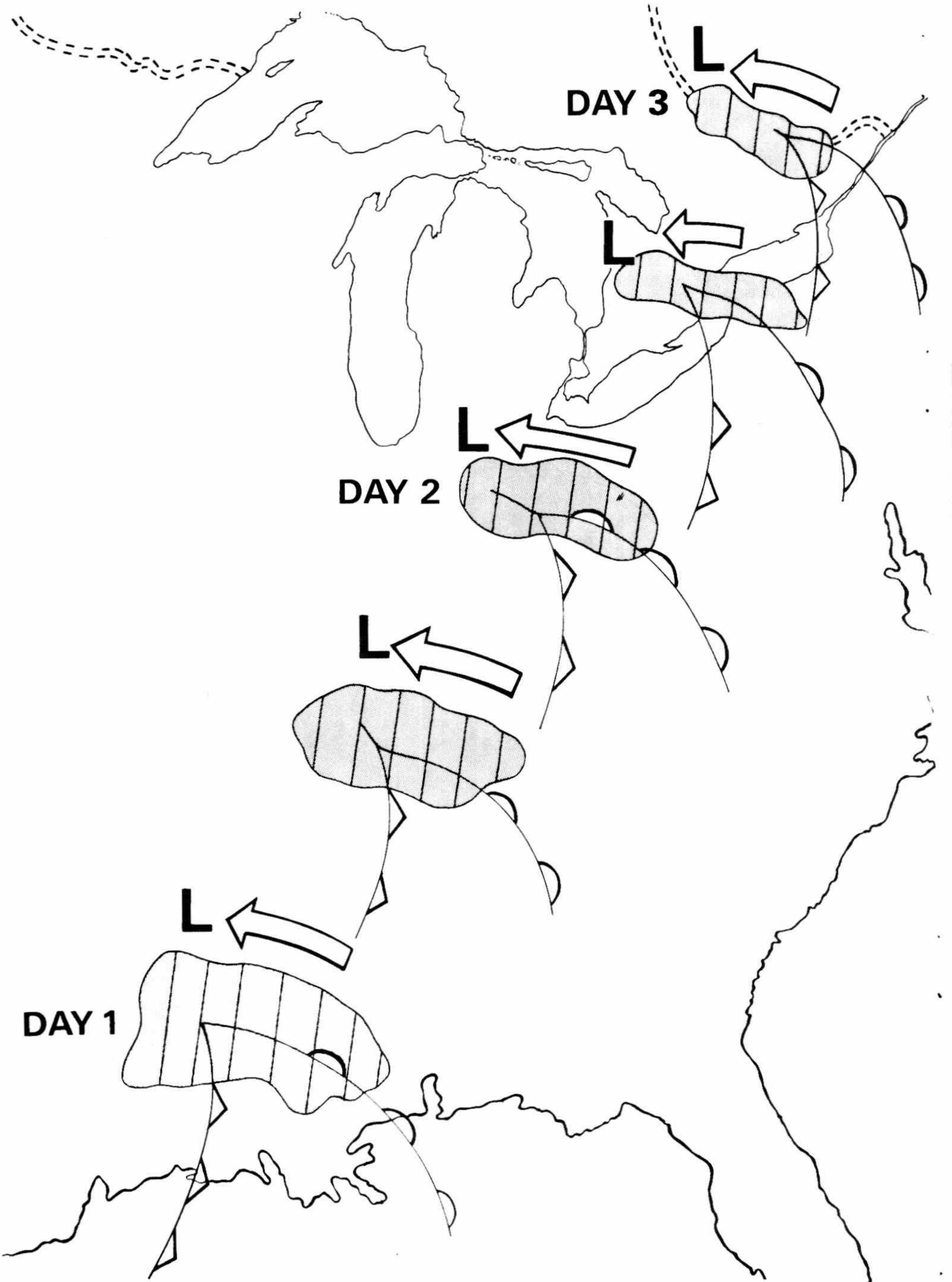


FIGURE 1 SAMPLE DEVELOPMENT OF NORTHEASTERN NORTH AMERICA WEATHER PHENOMENA

TABLE 1

SULPHUR DIOXIDE EMISSIONS NORTHEASTERN NORTH AMERICA

SOURCE	SO_2 EMISSIONS x 10^3 tons/yr. Urban	Utilities
CANADA		
Ontario	1,741.0	191.0
UNITED STATES		
Ohio	578.4	2,338.3
Indiana	433.5	1,666.4
Kentucky	74.2	1,387.7
Illinois	332.4	1,255.6
Michigan	189.4	1,158.8
Pennsylvania	535.5	1,119.6
West Virginia	149.7	1,020.9
Tennessee		721.4
Missouri	226.4	499.0
District of Columbia		216.5
New York	636.8	209.5
Wisconsin		192.1
Maryland	129.5	
Massachusetts	139.9	
Virginia	141.6	
U.S. Total	3,567.3	11,785.8

Second, as illustrated in Figure 2, a significant portion of the Province, principally Central, Northwestern and parts of Northeastern Ontario, are very susceptible to acidic inputs because of limited watershed buffering capacities. This is one of the reasons why many lakes in the Sudbury area are now devoid of fish and more importantly, is the reason why many recreational lakes in Muskoka-Haliburton will lose their fisheries if no action is taken.

Also, where acidic rain falls on terrain with little indigenous buffering or neutralizing capacity, irreversible changes can occur. These changes, requiring approximately ten years to manifest themselves, include physical and chemical characteristics of the waterways, benthic and plankton population composition shifts or elimination, and eventual loss of fisheries. This situation is aggravated by the knowledge that certain metal particulates, known to be detrimental to the environment, are also transported great distances. Finally, acidic precipitation can mobilize certain metals from the watershed, such as aluminum, thus further adding to the total. These metals apparently have reached concentrations which are toxic to many aquatic species in some Ontario lakes. There are observations that suggest that the uptake of mercury by fish is promoted by acidic conditions, although the mechanism is not well understood. In short, the ultimate result of acidic precipitation, combined with the deposition of metals, will be a significant reduction of Ontario's lake fishery resources. To date, the evidence indicates that this has happened near Sudbury and is now happening in other areas of Ontario. Therefore, the economic, recreational and aesthetic implications of this phenomenon necessitates that some remedial action should be taken as soon as possible.

There are five major study components, a brief sketch of these components is as follows:

(I) Sources and Atmospheric Transfer

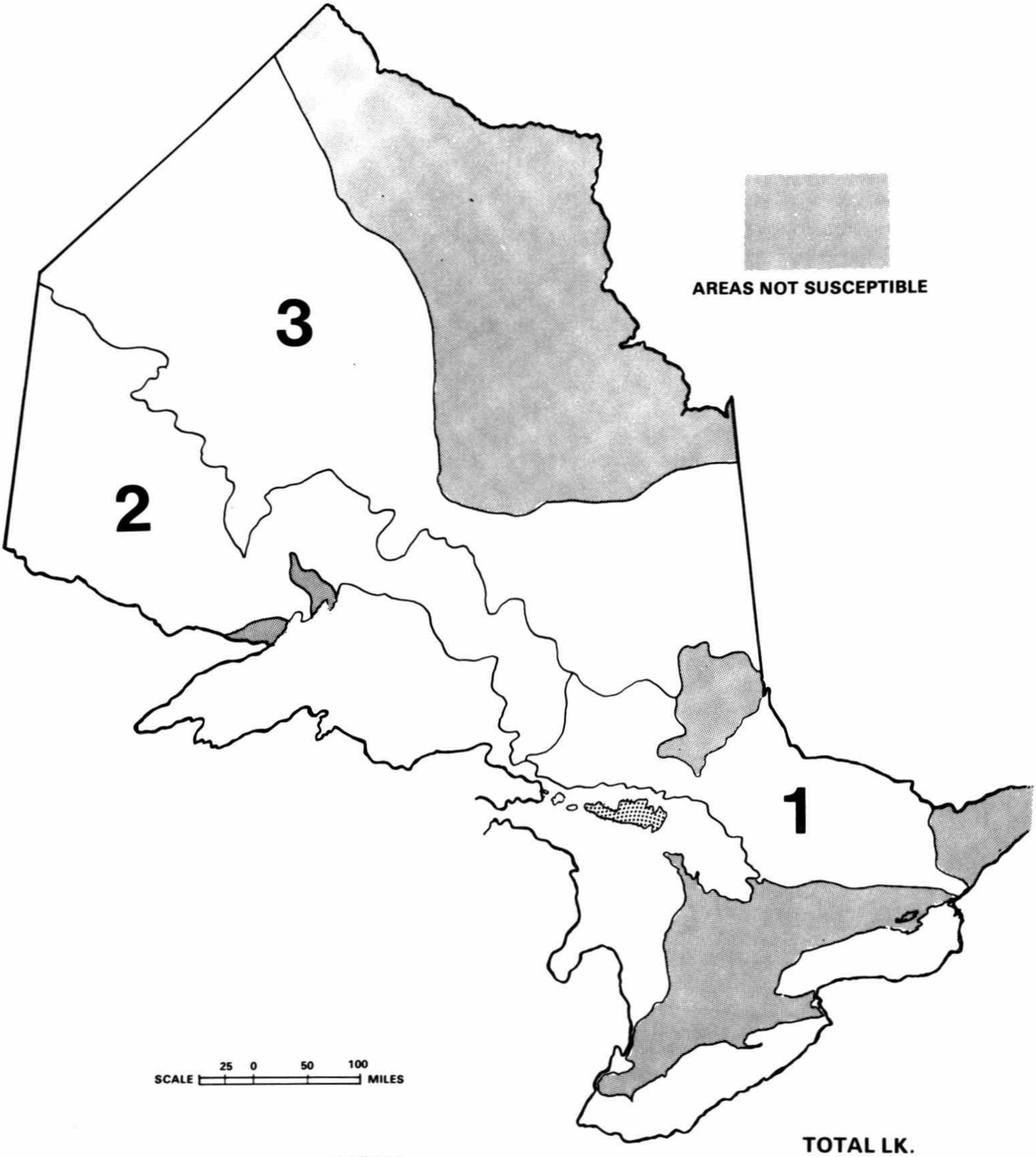
This component is responsible for distinguishing and then quantifying the long range and provincial components of the problem. For identified provincial sources, it includes direct measurement of the emissions in terms of chemical species and relative concentrations as well as identifying the atmospheric transfer mechanism, i.e.: tall stack, short stack, fugitive or low level, etc.

(II) Meteorology

Compilation of weather statistics over a sufficient time in sensitive areas of the Province together with both single source and urban physical and chemical plume studies, will allow appropriate models to be developed and refined. These models, in turn, will assist in predicting the results of changes in emission quantities and also aid in assessing the effectiveness of emission control strategies and provide a basis for negotiation with other governments.

(III) Sinks

The identification and determination of the relative importance of the numerous pollutant sinks is the final link in the important sequence: generation, transportation and dispersion, receptor and receptor concentration. Therefore, identification and quantification of specific sink mechanisms together with the accompanying meteorological data will allow model development and refinement and subsequently very accurate predictive capability.



CODE	TOTAL # OF LAKES	MEAN AREA/LK. (ACRES)	PERCENTAGE SUSCEPTIBLE	# OF LKS. SUSCEPTIBLE	TOTAL LK. AREA SUSCEPTIBLE (SQ. MI.)
1	40,589	58.9	50%	20,295	1,868
2	76,728	98.0	20%	15,346	2,350
3	64,133	130.0	20%	12,827	2,605
TOTALS:	181,450			48,468	6,823

FIGURE 2. TERRAIN WITH LAKES SUSCEPTIBLE TO PRECIPITATION ACIDITY

(IV) Environmental Impact

After the pollutant species and associated data are collected, and a model for estimating transport to specific segments of the environment is produced, impact assessments can be made and budget models developed to discern the relative importance of the various pollutants, currently emitted, with respect to vegetation, soils, the watershed and their inhabitants.

It is important to realize that the environment and its ecosystems are extremely complicated. Furthermore, cumulative interactions and complex synergisms, between various environmental segments and pollutants, are both subtle to detect and very complex in nature, thus making it extremely difficult not only to develop predictive models, but to assess the separate and/or cumulative contributions of any one pollutant or set of pollutants.

(V) Remedial Measures

Development and refinement of models associated with this study will allow for the reliable estimation of the environmental impact of the various pollutants involved.

In cases where the local sources prove to be the major contributors, then steps could be taken to minimize their effects. These steps coupled with environmental maintenance programs, e.g. watershed stabilization via liming, would ensure that the local environment was not unacceptably altered by these pollutants.

On the other hand, in situations where the major contributor(s) lie outside of the jurisdiction of this Province, then other alternatives would have to be considered.

In any event, it is imperative that studies be undertaken and maintained to allow for both of these eventualities. Ideally, these studies should include the development of: soil stabilization and upgrading strategies, revegetation, and lake reclamation techniques.

Figure 3 schematically represents the interplay of the first three of these components.

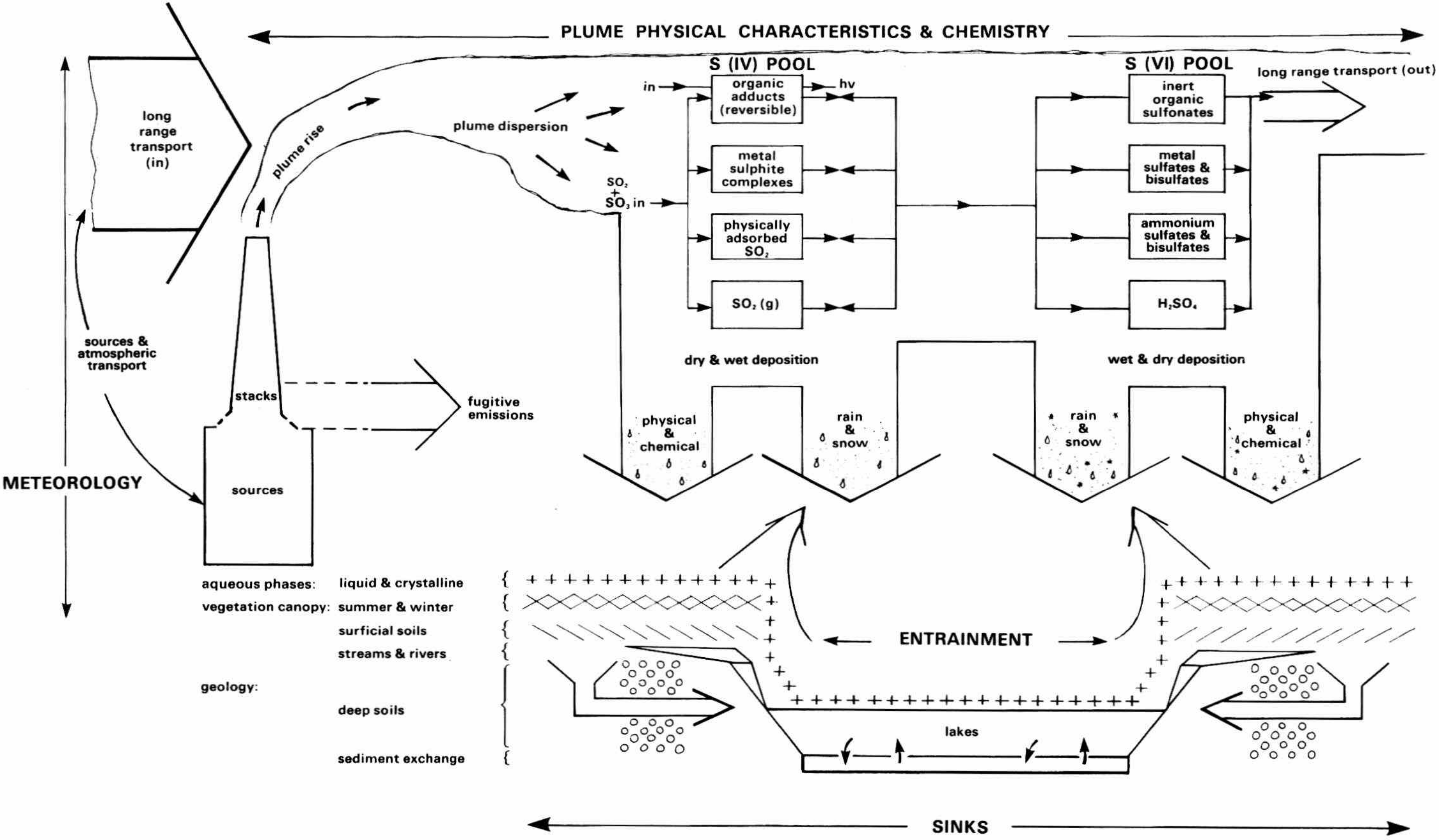


FIGURE 3. DIAGRAMATIC REPRESENTATION

INVENTORY OF APPLICABLE RESOURCES

The following constitutes an inventory of provincial, federal and international sources of information relevant to this program.

Provincial Resources:

Ministry of the Environment

Source	Applicable Strengths
Sudbury Environmental Study	Intensive deposition, dry and wet, monitoring networks in the Sudbury area. - Intensive meteorology statistics for Sudbury, including storm tracking statistics. - Development of a transport model specific to Sudbury. However, the developmental methodology has been learned and will be applicable on a wider scale in this new program. - A very large body of information, intensive on a small scale (5 Sudbury area lakes), extensive on a large scale (200 Sudbury area lakes), related to the degree and extent of watershed acidification in North-eastern Ontario. - Five years experience and data with respect to the success of some possible lake reclamation techniques and related fisheries toxicity data.
Air Resources Branch	Technology development and appraisal resources, specifically: (i) Nanticoke Environmental Management Program - Intensive deposition monitoring network in the Nanticoke Area. - Multi-agency contacts: private sector, international. - State of the art modelling expertise. - Appropriate sophisticated computational facilities. - Two full time highly competent staff.

(ii) Hazardous Substances Program

- The purpose of this program is to identify the source(s) of hazardous contaminants: some of these, possibly ozone and metals, acting as catalysts, may play an important part in the acidification phenomenon.

(iii) Source Assessment Unit

- The routine work of this unit involves the identification and quantification of pollutant sources in Ontario, some of which are applicable to this program e.g.: SO_x and NO_x sources and strengths in Ontario.

(iv) The Air Quality & Meteorology Section

- The Air Quality & Meteorology Section already has an extensive data bank on SO_x, NO_x, dustfall and sulphation concentrations as a function of time, for most major metropolitan areas in Ontario. In addition, this unit has extensive computer, statistical analysis and modelling capabilities.

(v) Phytotoxicology Section

- This unit has a tremendous data bank resource in terms of samples of soil and vegetation over many years over a great portion of the southern part of the Province. While the majority of those samples were procured for specific purposes, it may be possible to use some of them for preliminary trend in time analyses. The Head of this Section, Dr. S. Linzon, began growth studies in the Northeastern Region over 20 years ago. These studies have been followed up by a regional staff and may be of some use.

Water Resources Branch

(i) Lake Shore Capacity Study

- This program has a critically important body of data on several lakes in the Dorset area of the Muskoka/Haliburton District. These data have elucidated the broadening scope of the problem.

(ii) Limnology & Toxicity Section

- Significant limnological, toxicological, modelling, computational and provincial water data resources. Further necessary contacts with appropriate private, academic and federal agencies involved in similar programs. Also very important international contacts, e.g. U.S., Scandinavia.

Regions

- All six Regions have Technical Support Groups which have air and water quality expertise, experience and data. In particular: the Southeastern and Northeastern Regions have data related to the current status of many of the water bodies within their jurisdictions. This information will be taken into consideration when the selection of the watersheds to be intensively studied under the auspices of this study is actually carried out. In addition, both the Northeastern and Northwestern Regions have significant soil and vegetation data collected over many sampling seasons. Finally, each of the Regions has a large network of employees in all areas with the potential of collecting deposition samples at a nominal cost if supplied with appropriate instrumentation, and properly trained.

Other Provincial Ministries

Valuable data are being collected by the Lakeshore Capacity Study, although they are a by-product of the objectives of that program.

Academic Studies, Ontario

The following are included at this time:

(i) Dr. H. Harvey *et al*, University of Toronto, Chemical Algal, Zooplankton, and fish surveys on central Ontario lakes (including some of our study lakes as cross checks) to determine the variables controlling fish populations. Single sampling of 1,000 lakes under contract to Ontario Hydro.

(ii) Dr. T. Hutchinson and Dr. P. Stokes *et al*, University of Toronto - Studies of effects of Heavy Metals and Acidification on Biota in the Greater Sudbury Area including the Killary Lakes.

(iii) Dr. H. MacCrimmon, University of Guelph - Effects of Water Quality on Mercury Uptake in a Small Lake Near Georgian Bay.

(iv) Dr. J. Kramer, McMaster University - Surveys of Lakes and Precipitation, Particularly in Northwestern Ontario.

Federal Government

This section includes a brief description of the program and lists the responsible federal agency.

(A) Emissions Inventory:

(i) Emissions inventory for the Great Lakes deposition model

The E.P.S. Ontario Region gave assistance to the H. G. Acres contract to update and improve the emissions inventory being employed in the PLUARG atmospheric loading model. This effort was completed and all further emissions inventory activity was assumed by E.P.S. - A.P.C.D. in Ottawa.

The federal agency responsible is the E.P.S., Ontario Region.

(B) Atmospheric Dispersion and Transport:

(i) Long Range Transport

The tall-stack dispersion model has been updated with data from experimental measurements taken up to a distance of 400 to 500 km. Plumes from the INCO chimney have been detected passing over Toronto on several occasions. The final report is scheduled to appear during fiscal 1978/79.

The federal agency responsible is the A.E.S.

(ii) Dispersion

The regional scale dispersion model using the 127 km grid based on a wind field analysis is being carried out as a follow-up for further verification of the Acres dispersion model being completed under Section B (iii).

The federal agency responsible is the A.E.S.

(iii) Atmospheric loading model - Great Lakes Basin

Under contract support from PLUARG, the H. G. Acres Consultant Services has employed an Air Pollutant Emission, Atmospheric Transport and Deposition Model to model the deposition on the Great Lakes and Great Lakes Basin using data for 1973/74. A report was produced which will be included as a portion of the PLUARG report series. Estimates of the loading rates of $SO_4^{=}$, N, TP, Cd, Pb, Fe, and particulates were made using this model.

The federal agency responsible is the E.M.S.-C.C.I.W.

(C) Precipitation Quality Network

(i) Great Lakes precipitation network

Under the Canada/U.S. Great Lakes Water Quality Agreement a precipitation chemistry sampling network is operated as a contribution to the surveillance program. The network has been modified to include 10 wet-dry samplers of the Sangamo type. Four of the bulk samplers are being continued for data overlap comparison. Data are utilized to produce the annual atmospheric loading estimates for the I.J.C. and have been used in conjunction with other network measurements to provide loading estimates for PLUARG.

The federal agency involved here is the E.M.S. -I.W.D., Ontario Region.

(ii) Canadian Network for Sampling Precipitation (CANSAP)

The CANSAP network is a national network of precipitation sampling stations which supplement the W.M.O. network. Eleven stations are located in Ontario and employ the Sangamo wet-dry sampler identical to that employed in c (i). Samples are analyzed for major ions only under the CANSAP program. The C.C.I.W. program c (i) completes a nutrient and trace metals analysis on selected samples from this network.

The federal agency responsible is the A.E.S., Downsview.

(D) Special Studies of Precipitation

(i) Sulphur-Isotope Studies

Measurements of the sulphur-isotope content at stations located near the Sudbury sulphur source are being conducted to attempt to identify that portion of the $SO_4^{=}$ deposited with precipitation which is of organic origin. This effort may be able to identify the portion of precipitation acidity which has its cause in anthropogenic activities.

The federal agency responsible is the E.M.S. - C.C.I.W., Ontario.

(ii) Trace Metals in Atmospheric Deposition

Studies of metals and radioactive products, their deposition, pathways, uptake and interactions with the biological food chain are being undertaken.

This program is an integral portion of the geochemical food chain studies in the experimental lakes area. This study is conducted co-operatively with scientists of the Lamonte-Doherty Geological Observatory (U.S.A.), and is funded by the National Science Foundation in co-operation with the Fresh Water Institute.

The federal agency responsible is the F.M.S., Fresh Water Institute.

(E) Survey and Experimental Determination of Effects of pH and Contaminants on Forest Ecosystems

(i) Review of Current Knowledge

A preliminary survey of information on impact of pH changes on the forest ecosystem, review of current research, extent of problem and identification of areas of required research.

The federal agency responsible is the E.M.S., Great Lakes Forestry Research Centre.

(ii) Effects of pH and contaminants on primary productivity and biogeochemical cycling

Information on northern forest ecosystem structure and function: stability and resilience of ecosystem: impact of long-term, low level input of H^+, $SO_4^=$, etc., on element movement and on site productivity: eventual development of model to predict long-term impact of acidic precipitation on forest ecosystems.

The federal agency responsible is the E.M.S., Great Lakes Forestry Research Centre.

(iii) Hydrology and water quality

Monitoring pollution from atmospheric sources in small catchments over variable forest ecosystems. To be carried out at a level commensurate with primary studies on the impact of forestry practices on hydrological processes on forest ecosystems in Ontario.

The federal agency responsible is the E.M.S., Great Lakes Forestry Research Centre.

(iv) Effects on soil processes

The physical, chemical and biological characteristics of and processes in, forested soils pertinent to their ability to accommodate H^+, $SO_4^=$, etc., input: study mechanism of damage through vegetative change effect of pH and/or additions of toxic substances: determines the ability of soils to accommodate acidic inputs.

The federal agency responsible is the E.M.S., Great Lakes Forestry Research Centre.

(v) Economic studies of forest damage impact

Examine pollution problems in general from an economic point of view using data collected in other studies on the range of impact of pollution, the short- and long-term impact on trees, etc., and the effect of remedial action. To examine the economic impact of a pollution problem emanating from a point source and its impact on a social or industrial sector.

The federal agency responsible is the E.M.S., Great Lakes Forestry Research Centre.

(F) Experimental Simulation of Acidification of Soft Water Lakes to Determine Cause and Effect Relationships on Aquatic Communities Including Plants, Invertebrates and Fish

(i) Experimental acidification to determine cause-effect relationships at increased loading rates

The pH of a selected lake in the E.L.A. is being lowered by additions of strong acid (H_2SO_4) in quantities which aim to reduce the ambient pH by about 0.5/yr. Metal release and associated biosystems uptake and reactions are carefully measured as acidification progresses. Sub-enclosures of the lake are treated with radioactive tracers of several metals at a range of pH regimes to examine mobilization and food chain effects.

The federal agency responsible is the F.M.S. (Fresh Water Institute).

(ii) Water Budget Studies

Precipitation chemistry monitoring at the E.L.A. as part of the water balance program, includes the monitoring, over short time intervals, of resident times on terrestrial areas and lake evaporation for small basins.

The federal agency responsible is the F.M.S. (Fresh Water Institute).

OTHER COUNTRIES

United States

Many U.S. agencies are involved in programs which are of great use in this study. In particular:

(i) U.S. Department of Agriculture (USDA) Network. The U.S.D.A. has commenced the installation of a nationwide network of roughly 100 wet only samplers. It is their intent that roughly 25 of these samplers be installed by the end of July, 1978, with the remainder installed over the next two years. This network will be very similar to the F.E.C.'s CANSAP Network and will yield similar data (i.e. monthly composite wet only samples). These, coupled with the rain gauge data, will allow for the determination of the wet deposition field on a monthly basis.

(ii) Sulphate Regional Experiment (SURE), Multi-Static atmospheric Power Production Pollution Study (MAP3S) and the Sulphate Transformation and Transport Experiment (STATE). Although each of these is a distinct and separate program funded by different agencies, with their own goals and objectives, there is overlap as well as many complimentary components. These are large scale projects with an annual expenditure totalling nearly $8 million.

A summary of the above mentioned projects with sponsoring agency, level of funding, and projected duration follows:

1) SURE Electric Power Research Institute (EPRI), total funding - $6 million, expected life span 1977-1978.

2) MAP3S Study Program, currently funded under the auspices of the U.S.-EPA formerly under the auspices of the U.S.-DOE. Total funding is $9 million. Duration of expenditure 1977-80, probable extension.

3) STATE, under the auspices of the U.S.-EPA, total funding to date, unknown: $3 million in the first year. A multi-year program commencing in 1978 with total duration unknown at this time.

Scandinavian Programs

Studies of a similar nature have been undertaken in several Scandinavian countries for over 20 years, e.g. the program to lime over 500 lakes in Sweden, the S.N.S.F. in Norway, etc.

Every effort will be made to contact the governments and scientists involved in order to exchange results and to learn from their experience.

SYNOPSIS OF CURRENT KNOWLEDGE

1. Acidic precipitation is falling in many parts of the world and the consequences have been recorded in susceptible lakes. Lakes sufficiently acidified to cause a loss of their fisheries have been observed in Sweden, Norway, New York State, Nova Scotia, Maine and Scotland in addition to Ontario. Sweden has 90,000 lakes and predictions are that 50% will become acidic within the next 10 years. About 10,000 lakes are acidic now. In the Adirondacks, more than 50% of the lakes at elevations above 600 meters are now acidic and without fish.

2. Sulphur and nitrogen oxides emitted into the atmosphere are oxidized to various sulphates and nitrates, including sulphuric and nitric acids. The presence of these substances results in increased acidification of precipitation.

3. From the available information the main contributor to acidic precipitation is sulphuric acid with a contribution from nitric acid being in the range of 20 to 50% depending on location and storm source.

4. In the Northeastern U.S., at least 15 x 10^6 tons of SO_2 are released annually. The figure for Ontario is approximately 2 x 10^6 tons. The annual U.S. emissions of NO_x are approximately 24 x 10^6 tons while those for Ontario are estimated at 0.66 x 10^6 tons.

5. The rate of atmospheric oxidation of sulphur dioxide varies from less that 1% per hour to around 12% per hour, depending upon atmospheric conditions. As a consequence of this slow conversion rate, the SO_2 emitted can influence the acidity of precipitation at other locations far removed from the point of emission. The range of influence is generally believed to be of the order of 1500 km, but could be more or less in special circumstances.

6. The movement of weather systems across North America results in a major influx of polluted air parcels from the United States which contributes significantly to the deposition of acidic substances by both wet precipitation and dry deposition processes. A large percentage of the air masses associated with precipitation come from the southwest.

7. Event and cumulative precipitative data collected in the Sudbury area during the summer of 1978, when both INCO and Falconbridge ceased operations for several weeks, have shown that even in the absence of smelter operations there is a significant acid loading in the Sudbury area associated with precipitation. Further, the data from the limited monitoring period show no significant difference between shutdown and operating period precipitation acidities. A similar conclusion applies to acid loading. This observation suggests that the contributions due to INCO and Falconbridge to the acidic precipitation problem in the Sudbury area in the long-term, are relatively small compared to the component originating from long range transport. However, one cannot definitely conclude that smelter operations have no effect on the above parameters on a localized scale - the result is largely due to the sizeable acidic input from sources outside the Sudbury area.

8. The pH of precipitation in Southern Ontario usually lies between 3 and 5. The average value is in the vicinity of 4 which represents a significant increase (nearly 40 times) in acidity over that which occurs naturally due to atmospheric CO_2 (5.6). Numerous recorded events in the past year have had a pH equal to or less than 4.0. Snow cores taken on the study lakes and watersheds at the end of the winter had pH's of 4.0 to 4.3.

9. In soil acidification the effects observed are reduced pH, reduced cation exchange capacity, increased mobility of Al, Mn and Fe, and changes in biological activities.

10. With regard to vegetation, several effects have been found experimentally using simulated acid rain but there has been no direct proof to date that ambient acid precipitation has caused significant effects on natural forests in Sweden, Northeastern United States and Ontario.

11. Acidification of Precambrian lakes near Sudbury by atmospheric acid sources has been well documented. This documentation has indicated that 20% of the lakes in the study area have been acidified and that 50% have a calcite saturation index indicating little or no remaining buffering capacity.

12. In some streams the alkalinity was significantly reduced during spring runoff even though it was not reduced enough to effect the pH. However, several streams in the Haliburton area have pH's below 4.5 at all times. There is very little buffering capacity in the watersheds of these streams.

13. If recently-recorded loadings of acidic material to the study lakes in the Haliburton area continues, then in many of these lakes the alkalinity will be exhausted within five to ten years.

14. The alkalinity in Clear Lake, Haliburton, has been decreased from 1.7 mg/L in 1967 to 0.5 mg/L in 1977. This indicates a very significant change in the buffering capacity and points towards eventual elimination of any fishery in the lake.

15. Periods of heavy rainfall resulting in very acidic runoff in the Haliburton area have indicated that the buffering capacity of the soil is either depleted or cannot be made available fast enough to neutralize the acidic input. Studies done in the past two years have shown that acidic snow resulted in severe depressions of pH in streams and surface water of lakes during the spring runoff. The maximum increase in hydrogen ion concentration in the ten streams surveyed to date was up to 15 times the annual average. A spring pH depression is coincident with spring spawning of some species of fish and amphibians.

16. There were serious pH depressions in a number of the study lakes in the spring of 1978. Lakes that normally have a similar pH of 6.2 to 6.8 (e.g. Harp and Jerry Lakes) had pH's of only 5.4 to 5.9 in the mid-lake areas. The littoral (shoreline) pH's were 5.0 to 5.3 in Harpe Lake compared to 5.9 in the main body of the lake in the spring and 6.7 in the summer; 4.8 to 5.2 in the littoral zone of Chub Lake compared to 5.3 in the mid-lake in the spring and 6.0 in the summer. pH values below 5.5 will reduce fishery production.

17. Precipitation in the Haliburton area contains elevated concentrations of copper, nickel, zinc, lead and manganese compared to Kenora which is far removed from industrial sources in Eastern North America.

18. Aluminum and manganese levels, means of 49 and 51 ug/l respectively, in 14 lakes were elevated in rivers and lakes due to a leaching from watersheds by acidic precipitation. These concentrations may be toxic to fish in some cases. Littoral or shoreline concentrations were 100 to 200 ug/l in some lakes in spring, levels which in combination with low pH, may present severe problems to spawning fish.

19. In two study lakes close to Sudbury, the pH was artificially adjusted back to normal with lime and calcium carbonate but metal concentrations still remained at levels toxic to fish.

20. Sediment cores from non-mixed lakes in the Haliburton area (no oxygen at the bottom and, therefore, no organisms to mix up the sediments) indicate increased lake loading of lead, nickel, copper and cadmium over the past 30 ± 10 years.

21. Some observations indicate that low pH conditions in the lake water are associated with mercury accumulation in fish although the mechanism is not well understood at this time.

22. It has been observed in Ontario, that walleye from lakes of low alkalinity contain higher levels of mercury than the same size of walleye from lakes of higher alkalinity, even though the pH may not be significantly different.

PRESENT & PLANNED ACTIVITIES

On the initiative of the Ministry of the Environment, Steering and Technical Committees have been formed and a Coordinator has been appointed. Members include both M.O.E. and M.N.R. Regional and Central employees. The Federal Government will also be represented at the Technical Committee level. These committees have agreed to terms of reference. The general objective of the study is:

- To develop a strategy to protect the Ontario environment based on the study findings.

More specifically:

- To prepare a state-of-the-art report on the acidic deposition phenomena with emphasis on cataloguing the experiences gained in similar programs in Europe and North America.
- To establish contact and ensure continued close co-ordination with other agencies both Federal and International who are concerned with this issue.
- To determine the atmospheric transport and deposition of acids and acid forming materials, metals and other relevant constituents for Ontario.
- To determine the effects of atmospheric deposition on aquatic ecosystems including: water quality, phytoplankton, zooplankton and fish communities.
- To determine the effects of atmospheric deposition on terrestrial ecosystems.
- To develop effective air pollution abatement alternatives.
- To design cost-effective interim mitigative programs to preserve and rehabilitate affected aquatic and terrestrial ecosystems.

In order to properly address this problem, a major effort will be undertaken to efficiently align and employ all appropriate M.O.E. programs and expertise. In addition, efforts are being made to tie in related programs in the Ministries of Housing, Industry and Tourism, Northern Affairs and Natural Resources. Further, technical information exchanges will be cultivated with appropriate U.S., European and Scandinavian agencies engaged in similar activities. Finally, provincial lottery funds are being allocated where appropriate to university research groups to support ancilliary studies.

Current plans call for a two phase study. The first phase, already under way, is two years in length and will determine the scope and severity of the problem and will focus on developing economically feasible schemes for maintaining lake fisheries. The second phase will be based on the results of phase one and will involve a long-term commitment to mitigative measures while appropriate abatement strategies are developed, refined and implemented. This approach is dictated by the continental nature of the problem.

In essence, this means that present air monitoring networks will be expanded to adequately cover those areas of the Province deemed most susceptible to continued atmospheric acidic input. Further, an intensive Province-wide lake sampling program will be initiated to determine those lakes most susceptible to this phenomenon. Lakes described as susceptible will then be put into one of several categories. Those lakes categorized as having viable economic fisheries or fisheries of special or historic interest will be designated as appropriate for artificial maintenance.

These lakes will then be artificially maintained and their fisheries preserved and enhanced until long-term abatement solutions can be worked out with all levels of governments involved.

GLOSSARY OF TECHNICAL TERMS

ACIDIC LAKE:	A lake with a pH equal to or less than 5.5 (see pH).
BIOMASS:	The total mass of biologically active or living organisms in a given or defined volume of water.
BIOTA:	The plant and animal life in a region or lake.
BUFFERING:	The ability to neutralize or stabilize free hydrogen ion input.
C.S.I.:	Calcite saturation index. A means to estimate the remaining buffering capacity in a body of water.
DEPOSITION:	Refers to inputs to a surface from the atmosphere. These inputs have the following subdivisions. (i) Dry Particulate: Simply dry dust fallout e.g. road dust, tailing dust, sulphates, etc. (ii) Dry Gaseous: Fallout of atmospheric gas(es) onto suitable surfaces, e.g. leaves, road dust, lakes. (iii) Wet: Rain and snow and other forms of precipitation. NOTE: Deposition isopleths are lines joining points of equal deposition rates of any of the above. These plots are used to point out sources of pollutants.
DISPERSION:	The dispersing and mixing of pollutants with the atmosphere.
FUGITIVE EMISSIONS:	Emissions conveyed into the atmosphere usually from a large area, often uncontrollable; e.g. from a coal pile due to strong winds.
METEOROLOGICAL:	Pertaining to the weather.
OLIGOTROPHIC:	A body of water with high dissolved oxygen content and very little living matter in it. e.g. a lake with very clear transparent water.
OXIDATION RATE:	The speed with which a chemical species reacts with oxygen in the atmosphere.

pH:	A scale used to measure the concentration of free hydrogen ions in a sample of liquid. e.g. coke has a pH of 2.5, ordinary tap water usually has a pH of 7.
PLANKTON:	Very small animal and plant life living in water upon which many fish species feed. Zooplankton = animal plankton. Phytoplankton = plant plankton.
RECLAMATION:	With respect to lakes it means that the lake pH is returned to levels necessary to support fish life. Usually a pH > 5.5 is required. This is accomplished by adding a buffering agent e.g. limestone.
SINKS:	Location in the environment where a pollutant ends up. e.g. acidic rain ends up in lakes and oceans.
SYNERGISM:	The combined effect of two agents which results in an effect greater than the sum of effects of the individual agents. Like saying 1 + 1 = 3.
T.S.P.:	Total suspended particulates. A measure of the amount of dirt and dust suspended in a volume of air.